
Friday, June 13

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Session FA4
Room 4
8:30 - 11:30 a.m.

**Operational Aspects of Space
Radiation**

Solar Particle Events and the International Space Station

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The high inclination orbit for the International Space Station poses a risk to astronauts on EVA during occasional periods of enhanced high energy particle flux from the sun known as Solar Particle Events. We are currently unable to predict these events within the few-hour lead time required for evasive action. Compounding the threat is the fact that station construction occurs during increasing solar activity and through the peak of the solar cycle. In this paper we present an overview of the risk, the current methods to provide forecasts of SPEs, and potential risk mitigation options.

Radiation Environment on Mir and ISS Orbits During the Solar Cycle

M.V. Teltsov, M.I. Panasyuk and V.F. Bashkirov

The main components of the radiation environment in near Earth space are trapped radiation, galactic cosmic rays and Solar energetic particles. Now it is evident that all of these species undergo long-term variations associated with the solar activity cycle.

Since the 60's Skobeltsyn Institute of Nuclear Physics performed measurements of dose radiation onboard all Russian piloted missions.

The set of experimental data which was obtained during these missions gave unique information on long-term variations of radiation environment at the altitude of "Mir" station and is applicable to the future ISS "Alpha" mission.

The data analysis leads to the conclusion that the radiation hazard for the crew really exists, and due to variations of trapped radiation in the South Atlantic Anomaly.

During the long period of solar minimum radiation doses reach maximum values because of the cooling of upper layer of the atmosphere. The results of numerical simulation of these processes based on modern models of atmosphere, plasmasphere and geomagnetic fields are considered and compared in this paper.

New approach to Radiation Risk Assessment

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Mathematical models are developed which describe the radiation-induced mortality dynamics for homogeneous and inhomogeneous (in radiosensitivity) mammalian populations. These models relate statistical biometric functions with statistical and dynamic characteristics of critical systems in specimens belonging to these populations. The model of mortality for the inhomogeneous population involves two types of distributions, the normal and the log-normal, of its specimens with respect to the index of radiosensitivity for cells of the critical system.

The mortality model for the homogeneous population quantitatively reproduces the mortality rate of laboratory mice after exposure to very high doses of pulsed or continuous radiation when the small intestine is the critical system. This model also describes quantitatively the mortality of the same animals chronically irradiated at low dose rates when the hematopoietic system (specifically, the thrombocytopoiesis) is the critical one. The mortality model for the inhomogeneous population predicts a higher mortality rate and a lower survival than it could have been predicted proceeding from the averaged values of the radiosensitivity index of the critical system cells. The level of doses and dose rates of acute and chronic exposures presenting a hazard to inhomogeneous mammalian populations is the lower the greater the variance of the corresponding distributions. For mammals having hyperradiosensitive precursor cells, even low-level radiation can have fatal consequences. These model results have considerable theoretical and practical importance since they outline new pathways in the development of methods of radiation risk assessment for planning the long-time space mission.

The work was funded in part by DNA/AFRRI (USA).

A INDUSTRIAL METHOD TO PREDICT MAJOR SOLAR FLARES FOR A BETTER PROTECTION OF HUMAN BEINGS IN SPACE

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Taking into account the solar flare occurrences begin to be a real problem for manufacturers of on-board electronic equipments.

Aerospatiale encountered the problem during the development of Ariane 5 launchers, and was lead to propose an empirical method to predict, with a good accuracy, the occurrence of a solar flare, before deciding a launch, and more precisely the particle flares which are the most dangerous for human beings.

This method could be used for the future manned flights of the CRV program, in order to define more precisely the periods during which the passengers have must be protected from radiation.

In the present communication, we first recall general information on the star « SUN », its structure, what is defined as « solar cycle », and the description of the areas on the SUN surface as called « actives zones ».

We define next what are the mechanisms which signal the occurrence of a solar flare, and the electromagnetic waves which can be detected just before the event.

We then go through the specific case of particle flares (rich in protons and heavy ions), which are the most dangerous ones for human beings.

We examine the particle flares from the last three solar cycles, essentially through GOES information given by Boulder's prediction centre. We then propose criteria which could have announced the solar events; those a posteriori criteria are summerized, in order to define the most important ones.

We finally define procedures to de followed in order to predict solar particle flares, from an industrial point of view; i.e. by using directly the « Today's Space Weather », service proposed by the Space Environment Centre of Boulder(US).

The most important procedure is to follow the « Space Weather Outlook » and the « X-rays flux » figures. The indications for a major event leading to the emission of particles would be the occurrence of a special output on the X-ray flux.

This observation has been correlated to almost all the major events for the last three cycles.

This work has been supported by the French Space Agency, with the collaboration of such specialized scientific laboratories as ONERA/CERT and the French Solar Flare Prediction Centre of Meudon.

The validity of the identified criteria will be tested during the next solar cycle, for which maximum activity period will take place after 1997.

Description of the Space Radiation Control System for the Russian Segment of ISS

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The Space Radiation Control System will be developed to be placed at large inhabited space objects with a long living time. System will consist of:

- 1. Radiation Environment Modeling Unit** accepts the ballistic parameters from the board systems (once per circuit) and object orientation information (continuously). Basing on the implemented Earth Magnetosphere Counting Model, the Unit calculate the estimated profile of the radiation intensity per 24 hours forward, and passes it by cosmonauts request to the board indication units, in a graphics form. The Unit uses the solar activity data, received from Earth in the counting process;
- 2. Stationary Dosimeter (DOSTEL)** is used for radiation dose measurements in the internal volume of the object with high sensitivity. Detector part consists of two silicon detectors (600 mm² each) with thickness of 0.3 mm, placed one under another in 15 mm distance;
- 3. Penetrating Radiation Spectrometer** is placed outside of the object. It measures the flux and the spectrums of electrons with energies of 0.1 - 10 MeV, protons and nucleuses with energiies of 1 - 200 MeV/nucleon, an x-rays with energies of 10 - 100 keV. Dynamic range of the counting rate is from 10⁻² to 10⁵ particles per second. The purpose of unit is the monitoring of the magnetosphere particle population. Detector part of the unit is based on a CsI(Tl) crystal and CsI(Na) crystal. Passive and active shield from the plastic and Pb glass, so as the method of front-based pulse division, allows to register the different types of particles separately.
- 4. Mobile Radiation Exposure Control Subsystem (MRECS)** main purpose is to be monitored simultaneously the doses and fluxes at four independent places of the segment. In case of special study the subsystem can be used for personal monitoring of the doses and fluxes obtained in 5 days by 4 selected cosmonauts. The subsystem consists of 4 Mobile Dosimetry Units (MDU), 4 Stationary Dosimetry Units (SDU) and one Control and Interface Unit (CIU). Further developments of the subsystem will allow extending of the number of MDUs, SDUs and ICUs up to 64.

All units of the Radiation Control System are connected with board systems by the Ethernet network. Information from dosimeters and spectrometers of the System, and the results of modeling, are passed to the Earth, to define the model correctness. The model coefficients can be corrected from Earth.

Orbit Selection and Its Impact on Radiation Warning Architecture for a Human Mission to Mars

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With the recent announcement of the discovery of the possibility of life on Mars, there is renewed interest in Mars missions, perhaps eventually in manned missions. Astronauts on such missions are at risk to occasional periods of enhanced high energy particle flux from the sun known as Solar Particle Events. These events can pose a substantial risk to the health of the astronauts and to the on-board electronics. Effective forecast and warning of these events could provide time to take steps to minimize the risk (retreating to a safe haven, shutting down sensitive equipment, etc.) Providing that forecast capability will require additional monitoring capability. The extent of this architecture is sensitive to the orbit selected for the transfer to and from Mars. This paper looks at the major classes of Mars missions (Conjunction and Opposition) and sub-categories of these classes and draws conclusions on the number of monitoring satellites needed for each, with a goal to reducing total system cost through optimum orbit selection.

**Space Nuclear Power:
Technology, Policy and Risk Considerations
in Human Missions to Mars**

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This paper discusses the disconnect between the stated requirement for nuclear propulsion and power systems for human exploration of Mars and the current status of R&D funding for these technologies. Mission planners and spacecraft designers, energized by the recent claims of possible discovery of life on Mars and responding to increased public interest in the crewed exploration of Mars, frequently propose nuclear reactors for interplanetary spacecraft propulsion and for power supply on the surface of Mars. These plans and designs typically assume the reactors will be available “on-the-shelf,” and do not take the extensive research and development costs required to develop such reactors into consideration. Current U.S. policies, if unchanged, will prohibit the launch of nuclear reactors.

Recent work by the National Academy of Sciences on space nuclear reactors is reviewed and recent Congressional action canceling the last U.S. research program supporting this technology is addressed. Radiation risk to humans from nuclear powered spacecraft and nuclear power systems on the surface of Mars is considered. The current state of nuclear space technology is discussed and possible necessary changes in the policies of the United States to allow the development and launch of crewed nuclear powered spacecraft are proposed.